UNIT # 6
WORK AND ENERGY

Q1. Define work. What is its SI unit?

Ans: Work:

Work is done when a force acting on a body displaces it in the direction of a force.

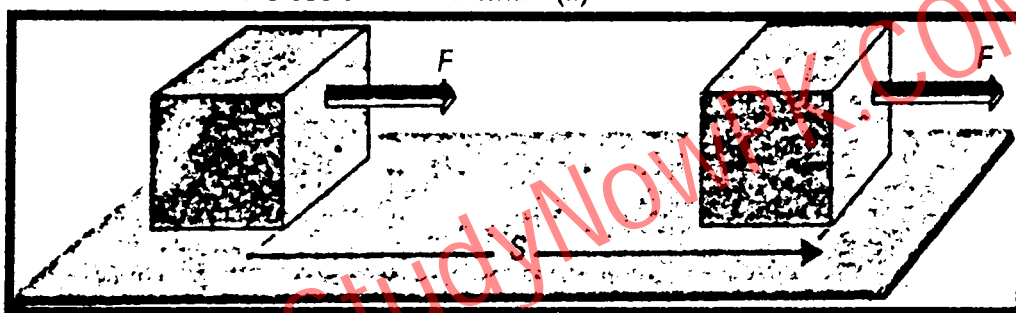
Work is a scalar quantity. It depends on the force acting on a body, displacement of the body and the angle between them.

$$\text{Work done} = \text{Force} \times \text{displacement}$$

or $W = F\,S$ .... (i)

$W = F_x \times S$

$W = (F \cos\theta)\, S$

$W = F\,S \cos\theta$ .... (ii)

Work done in displacement a body in the direction of force.

Unit of work:

SI unit of work is joule (J). It is defined as

The amount of work is one joule when a force of one newton displaces a body through one metre in the direction of force.

Thus $1\,J = 1\,N \times 1\,m$

Q2. Derive the relation for work done by a force inclined with the displacement?

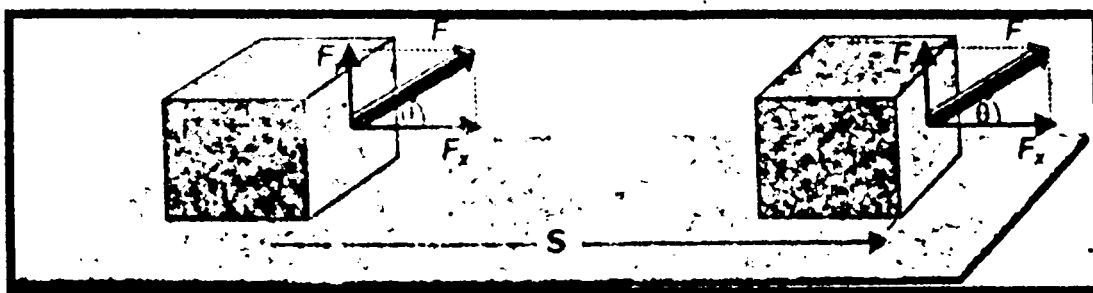
Ans: Let the force **F** is making an angle θ with the surface on which the body is moved. Resolving F into its perpendicular components F_x and F_y as;

$$F_x = F\cos\theta$$
$$F_y = F\sin\theta$$

In case when force and displacement are not parallel then only the x-component F_x parallel to the surface causes the body to move on the surface and not the y-component F_y.

Hence $W = F_x \times S$

$= (F\cos\theta)\, S$

$= F\,S\cos\theta$

Work done by a force inclined with the displacement.

Mini Exercise

A crate is moved by pulling the rope attached to it. It moves 10 m on a straight horizontal road by a force of 100 N. How much work will be done if.

1. the rope is parallel to the road.

Solution: Force = 100 N
Distance = S = 10 m
Work = W = ?
W = F × S
W = 100 × 10 = 1000 J

2. the rope is making an angle of 30° with the road.

Solution: Force = 100 N
Distance = S = 10 m
$\theta = 30^\circ$
Work = W = ?
$W = FS\cos\theta$
$W = 100 \times 10\cos(30^\circ)$
$W = 1000 \times (0.866) = 866$ J

Q3. Define energy, give two types of mechanical energy.

Ans: Energy:

A body possesses energy if it is capable to do work.

Types of mechanical energy:

Mechanical energy possessed by a body is of two types: kinetic energy and potential energy.

Q4. Why do we need energy?

Ans: See Q # 6.4 from Exercise.

Q5. Define K.E. and derive its relation.

OR

Prove that $K.E. = \frac{1}{2}mv^2$

Ans: See Q # 6.6 from Exercise.

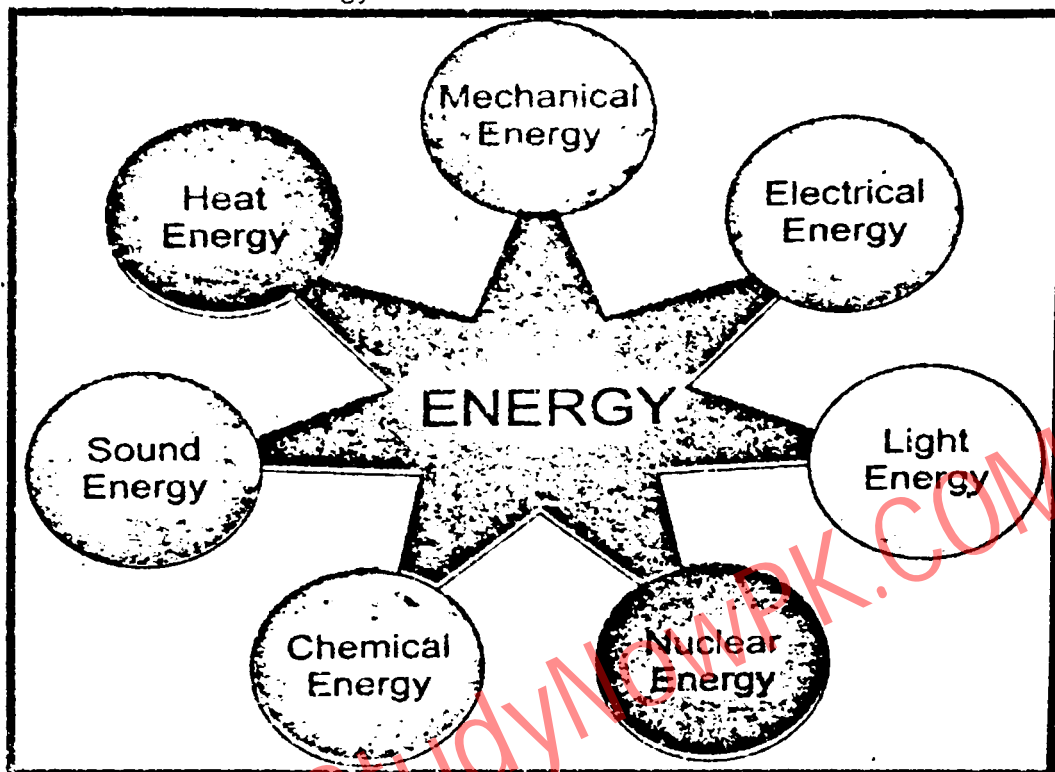
Q6. Define potential energy and derive its relation.

Ans: See Q # 6.7 from Exercise.

Q7. List the different forms of energy with examples?

Ans: Forms of Energy:

Energy exists in various forms. Some of the main forms of energy are given:

i.	Mechanical energy	ii.	Heat energy
iii.	Electrical energy	iv.	Sound energy
v.	Light energy	vi.	Chemical energy
vii.	Nuclear energy		

Some of the main forms of energy

Q8. Describe mechanical energy with examples?

Ans: Mechanical energy:

The energy possessed by a body both due to its motion or position is called mechanical energy.

Examples:

Water running down a stream, wind, a moving car, a lifted hammer, a stretched bow, a catapult or a compressed spring etc. possesses mechanical energy.

Q9. Describe heat energy with examples?

Ans: Heat energy:

Heat is a form of energy given out by hot bodies. Large amount of heat is obtained by burning fuel. Heat is also produced when motion is opposed by frictional forces. The foods we take provide us heat energy.

Examples:

The Sun is the main source of heat energy.

Q10. Describe electrical energy with examples?

Ans: Electrical energy:

Electricity is one of the widely used form of energy. Electrical energy can be supplied easily to any desired place through wires.

Examples:

We get electrical energy from batteries and electric generators. These electric generators are run by hydro power, thermal or nuclear power.

Q11. Describe sound energy with examples?

Ans: Sound energy:

When you knock at the door, you produce sound. Sound is a form of energy.

Examples:

It is produced when a body vibrates; such as vibrating diaphragm of a drum, vibrating strings of a sitar and vibrating air column of wind instruments such as flute pipe etc.

Q12. Describe light energy with examples?

Ans: Light energy:

Light is an important form of energy. Name some sources of light that you come across.

Plants produce food in the presence of light. We also need light to see things.

Examples:

We get light from candles, electric bulbs, fluorescent tubes and also by burning fuel. However, most of the light comes from the Sun.

Q13. Describe chemical energy with examples?

Ans: Chemical energy:

Chemical energy is present in food, fuels and in other substances. We get other forms of energy from these substances during chemical reactions.

The burning of wood, coal or natural gas in air is a chemical reaction which releases energy as heat and light. Electric energy is obtained from electric cells and batteries as a result of chemical reaction between various substances present in them. Animals get heat and muscular energy from the food they eat.

Q14. Describe nuclear energy with examples?

Ans: Nuclear energy:

Nuclear energy is the energy released in the form of nuclear radiations in addition to heat and light during nuclear reactions such as fission and fusion reactions. Heat energy released in nuclear reactors is converted into electrical energy.

Examples:

The energy coming from the Sun for the last billions of years is the result of nuclear reactions taking place on the Sun.

DO YOU KNOW?

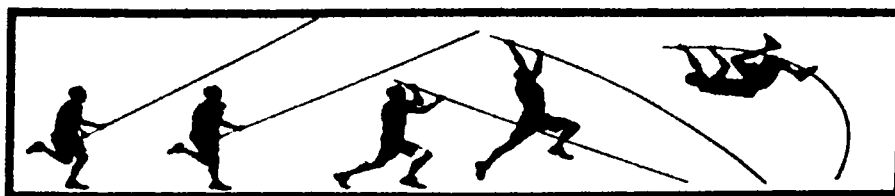
Our body gets energy stored in the food we take to perform various activities.

DO YOU KNOW?

A nuclear power plant uses the energy released in nuclear reactor such as fission to generate electric power.

Q15. How is energy converted from one form to another? Explain.

Ans: See Q # 6.10 from Exercise.

DO YOU KNOW?

Pole vaulter:

A pole vaulter uses a flexible vaulting pole made of special material. It is capable to store all the vaulter's kinetic energy while bending in the form of potential energy. The vaulter runs as fast as possible to gain speed. The kinetic energy gained by the vaulter due to speed helps him/her to rise up as the vaulter straightens. Thus he attains height as the pole returns the potential energy stored by the vaulter in the pole.

Q16. List the major sources of energy?

Ans: Major sources of energy:

i. Fossil fuels
ii. Nuclear fuels
iii. Energy from biomass
iv. Energy from water
v. Energy from the sun
vi. Solar house heating
vii. Solar cells
viii. Wind energy
ix. Geothermal energy

Q17. Differentiate energy resources as renewable and non-renewable resources of energy with examples of each?

Ans: Renewable resources of energy:

Renewable sources of energy are those which can be reused. They do not get extinguished. They are environmentally friendly they do not cause pollution.

Examples:

Solar energy, wind energy and tidal energy.

Non-renewable resources of energy:

Non-renewable sources of energy are those which cannot be reused. They get extinguished. They cause pollution and are environmentally harmful.

Examples:

Plastic, wood, petroleum, oil, etc.

Q18. List non-renewable sources of energy?

Ans: i. Fossil fuels **ii.** Nuclear fuels

Q19. Describe the processes by which energy is converted from one form to another with reference to fossil fuels energy?

OR

Q20. Why fossils fuels are called non-renewable form of energy?

Ans: See Q # 6.8 from Exercise.

Q21. Describe the harmful waste products released by fossil fuels?

OR

List the Environmental issues associated with fossil fuels?

Ans: Environmental issues associated with fossil fuels:

Fossil fuels release harmful waste products. These wastes include carbon mono-oxide and other harmful gases, which pollute the environment. This causes serious health problems such as headache, tension, nausea, allergic reactions, irritation of eyes, nose and throat. Long exposure of these harmful gases may cause asthma, lungs cancer, heart diseases and even damage to brain, nerves and other organs of our body.

Q22. Describe the processes by which energy is converted from one form to another with reference to nuclear fuels?

OR

List the Environmental issues associated with nuclear fuels?

Ans: Nuclear fuels:

In nuclear power plants, we get energy as a result of fission reaction. During fission reaction, heavy atoms, such as Uranium atoms, split up into smaller parts releasing a large amount of energy.

Nuclear power plants give out a lot of nuclear radiations and vast amount of heat. A part of this heat is used to run power plants while lot of heat goes waste into the environment.

Q23. List non-renewable sources of energy?

Ans:

i.	Energy from water	**ii**	Energy from the sun
iii.	Solar house heating	**iv.**	Solar cells
v.	Wind energy	**vi.**	Geothermal energy
vii.	Energy from biomass		

Renewable energy sources:

Sunlight and water power are the renewable sources of energy. They will not run out like coal, oil and gas.

Q24. How energy is obtained from water?

Ans: Energy from water:

Energy from water power is very cheap. Dams are being constructed at suitable locations in different parts of the world. Dams serve many purposes. They help to control floods by storing water. The water stored in dams is used for irrigation and also to generate electrical energy without creating much environmental problems.

Q25. How energy is obtained from sun?

Ans: Energy from the sun:

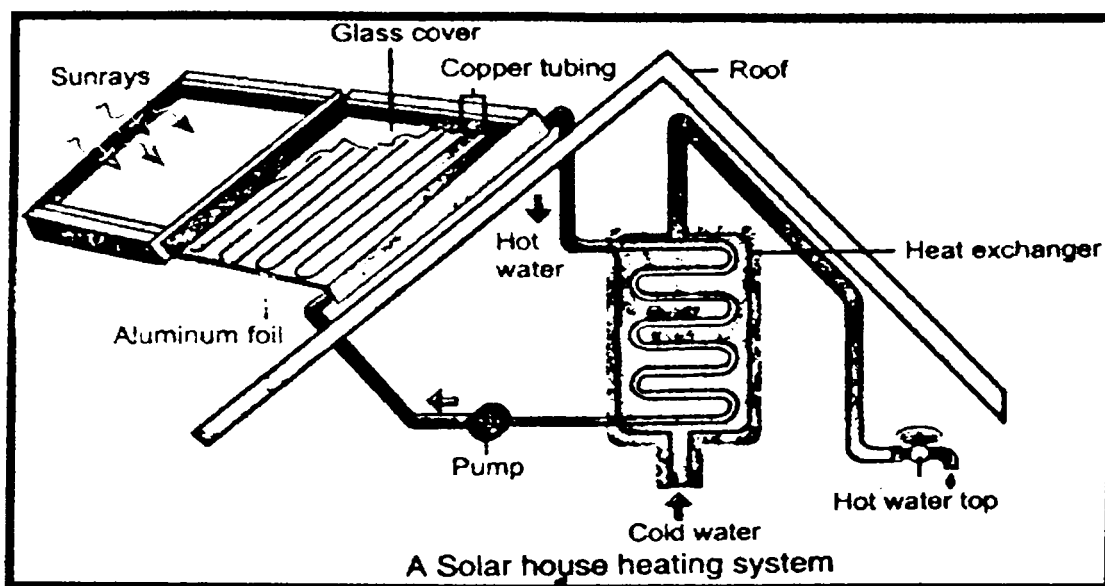
Solar energy is the energy coming from the Sun and is used directly and indirectly. Sunlight does not pollute the environment in any way. The sunrays are the ultimate source of life on the Earth. We are dependent on the Sun for all our food and fuels. If we find a suitable method to use a fraction of the solar energy reaching the Earth, then it would be enough to fulfil our energy requirement.

Q26. Explain the functioning of solar house heating system?

Ans: Solar house heating:

Complete solar house heating systems are successfully used in areas with a minimum amount of sunshine in winter. A heating system consists of:

i. A collector
ii. A storage device
iii. A distribution system

A Solar house heating system

Working of solar heating system:

A solar collector made of glass panels over blank metal plates. The plates absorb the Sun's energy which heats a liquid flowing in the pipes at the back of the collector. The hot water can be used for cooking, washing and heating the buildings.

Uses of solar energy:

Solar energy is used in solar cookers, solar distillation plants, solar power plant, etc.

Q27. Describe the process of electricity generated by solar cells?

Ans: Solar cells:

Solar energy can also be converted directly into electricity by solar cells. A solar cell also called photo cell is made from silicon wafer.

When sunlight falls on a solar cell, it converts the light directly into electrical energy. Solar cells are used in calculators, watches and toys. Large numbers of solar cells are wired together to form solar panels.

Solar panels can provide power to telephone booths, light houses and scientific research centres. Solar panels are also used to power satellites.

Q28. Describe the process of electricity generated by wind energy?

Ans: Wind energy:

Wind has been used as a source of energy for centuries. It has powered sailing ships across the oceans. It has been used by windmills to grind grain and pump water.

More recently, wind power is used to turn wind turbines. When many wind machines are grouped together on wind farms, they can generate enough power to operate a power plant.

In the United States, some wind farms generate more than 1300 MW of electricity a day. In Europe, many wind farms routinely generate hundred megawatts or more electricity a day.

Q29. Describe the process of electricity generated by geothermal energy?

Ans: Geothermal energy:

In some parts of the world, the Earth provides us hot water from geysers and hot springs. There is hot molten part, deep in the Earth called magma. Water reaching close to the magma changes to steam due to the high temperature of magma.' This energy is called geothermal energy.

Geothermal well can be built by drilling deep near hot rocks at places, where magma is not very deep. Water is then pushed down into the well. The rocks quickly heat the water and change it into steam. It expands and moves up to the surface. The steam can be piped directly into houses and offices for heating purposes or it can be used to generate electricity.

Q30. Describe the process of electricity generated by biomass?

Ans: Energy from biomass:

Biomass is plant or animal wastes that can be burnt as fuel. Other forms of biomass are garbage, farm wastes, sugarcane and other plants. These wastes are used to run power plants. Many industries that use forest products get half of their electricity by burning bark and other wood wastes. Biomass can serve as another energy source, but problems are there in its use.

When animal dung, dead plants and dead animals decompose, they give off a mixture of methane and carbon dioxide. Electricity can be generated by burning methane.

Q31. State mass energy equation $E = mc^2$.

Ans: Mass-energy equation:

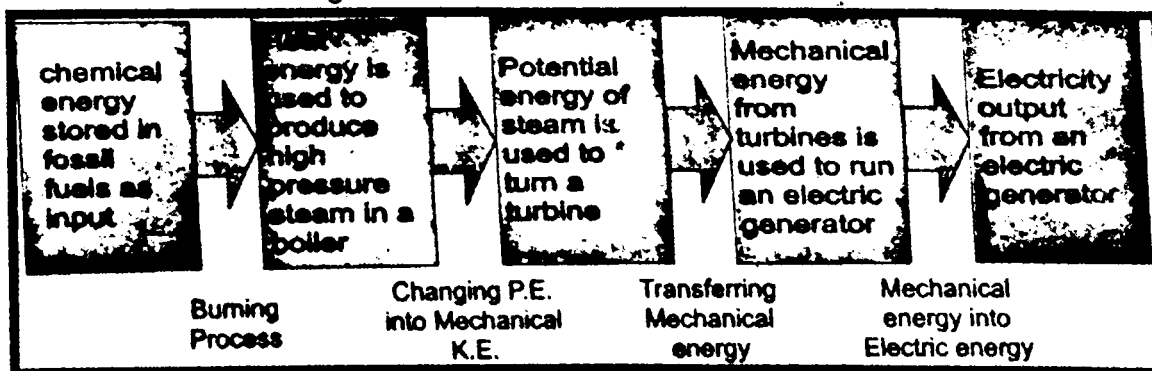
Einstein predicted the interconversion of matter and energy. According to him, a loss in the mass of a body provides a lot of energy. This happens in nuclear reactions. The relation between mass m and energy E is given by Einstein's mass-energy equation.

$$E = mc^2 \qquad \text{......... (i)}$$

Here c is the speed of light ($3 \times 10^8\ ms^{-1}$). The above equation shows that tremendous amount of energy can be obtained from small quantity of matter.

Q32. Explain by drawing flow diagram electricity from fossil fuels

Ans: Electricity from fossil fuels:

Most of the electricity is obtained using fossil fuels such as oil, gas and coal. Fossil fuels are burnt in thermal power stations to produce electricity. Various energy conversion processes involved in producing electricity from coal are described in a block diagram.

Several energy conversion processes are involved in producing electricity.

Q33. List the environmental issues associated with energy. Highlight the solution of these issues?

Ans: Energy and environment:

Environmental problems such as pollution that consist of noise, air pollution and water pollution may arise by using different sources of energy such as fossil fuels and nuclear energy.

Pollution:

Pollution is the change in the quality of environment that can be harmful and unpleasant for living things.

Thermal Pollution:

A temperature rise in the environment that disturbs life is called thermal pollution. Thermal pollution upsets the balance of life and endangers the survival of many species.

Air pollutants:

Air pollutants are unwanted and harmful. Natural processes such as volcanic eruptions, forest fires and dust storms add pollutant to the air. These pollutant, rarely build up to harmful levels. On the other hand, the burning of fuel and solid wastes in homes, automobiles and factories releases harmful amount of air pollutants.

Pollution produced by power plants and fission plants:

All power plants produce waste heat, but fission plants produce the most. The heat released into a lake, a river or an ocean upsets the balance of life in them. Unlike other power plants, nuclear power plants do not produce carbon dioxide. But they do produce dangerous radioactive wastes.

Controlling of pollution issues:

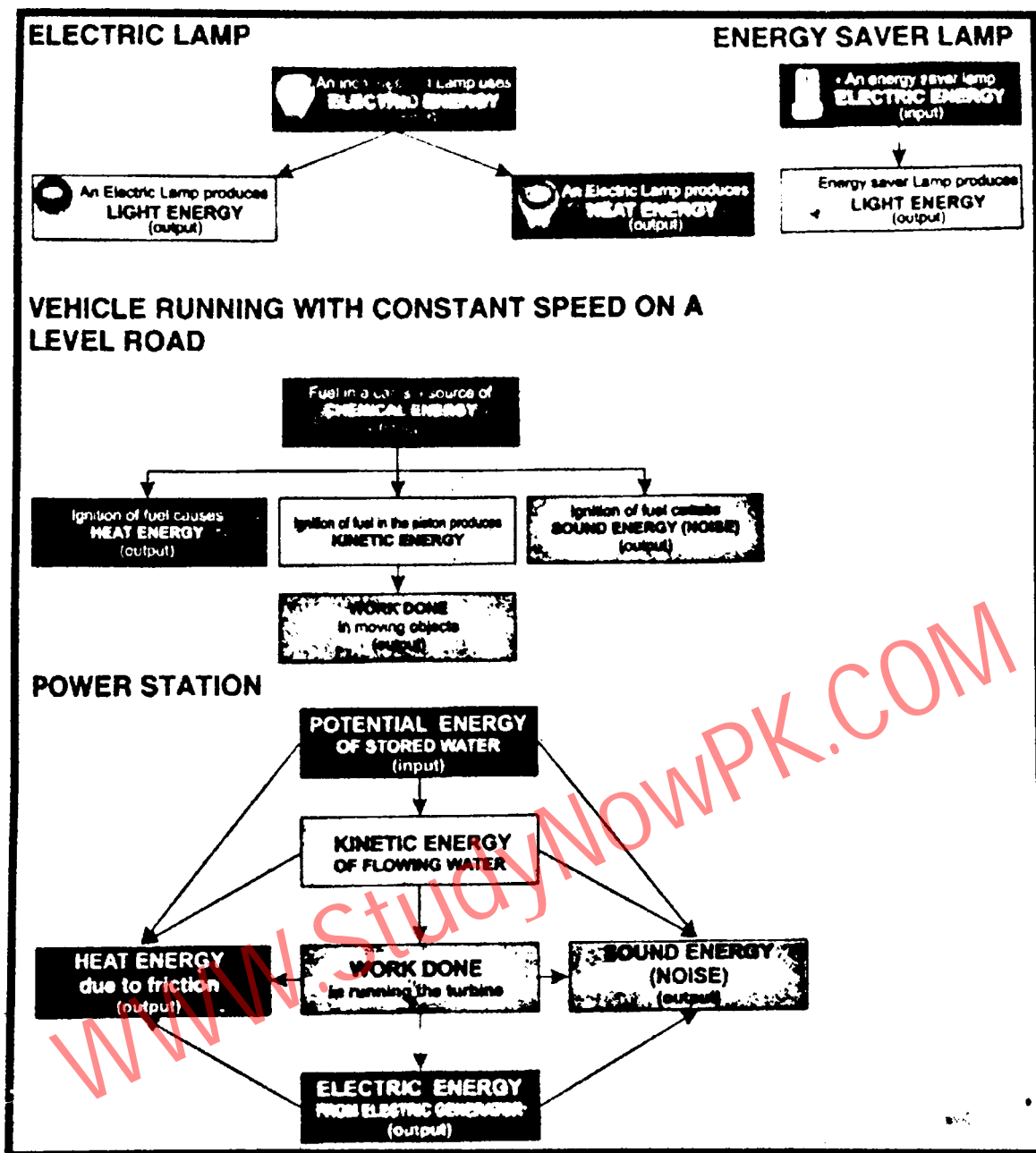
In many countries governments have passed laws to control air pollution. Some of these laws limit the amount of pollution that, power plants, factories and automobiles are allowed to give off. To meet these conditions for automobiles, new cars have catalytic converters. These devices convert some polluting gases. The use of lead free petrol has greatly reduced the amount of lead in the air. Engineers are working to improve new kinds of car engines that use electricity or energy sources other than diesel and petrol.

Many individual communities have laws which protect their areas from pollution. Individuals can help to control air pollution simply by reducing the use of cars and other machines that burn fuel. Sharing rides and using public transportation are the ways to reduce the number of automobiles in use.

Q34. Explain by drawing energy flow diagrams through steady state system such as filament lamp a power station, a vehicles travelling at a constant speed on a level road?

Ans: Flow diagram of an energy converter:

In an energy converter, a part of the energy taken (used up) by the system is converted into useful work. Remaining part of the energy is dissipated as heat energy; sound energy (noise) into the environment.

Energy flow diagrams given below show the energy taken up by an energy converter to transform it into other forms of energy.

Q35. What is meant by the efficiency of a system?

OR

How can you find the efficiency of a system?

Ans: Efficiency:

The ratio of the useful work done by a device or machine to the total energy taken up by it is called its efficiency.

OR

Efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input.

$$\text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}} \qquad \text{(i)}$$

Or

$$\%\ \text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}} \times 100 \quad \ldots\ldots\ldots \text{(ii)}$$

Ideal system/Ideal machine:

An ideal system is that which gives an output equal to the total energy used by it. In other words, its efficiency is 100 %.

People have tried to design a working system that would be 100 % efficient. But practically such a system does not exist.

ADDITIONAL INFORMATION

Efficiencies of some typical devices/machines			
Energy Input	**Device or Machine**	**Useful Work done**	**% Efficiency**
100 J	Electric Lamp	5J	5%
100 J	Petrol Engine	25 J	25%
100 J	Electric Motor	80J	80%
100 J	Electric Fan	55J	55%
100 J	Solar Cell	3J	3%

Q36. What is meant by the term power? Define watt.

Ans: See Q # 6.15 from Exercise.

SUMMARY

1. **Work:** Work is said to be done when a force acting on a body moves it in the direction of the force.
   - Work $= FS$
   - SI unit of work is joule (J).
2. **Energy:** When we say that a body has energy, we mean that it has the ability to do work. SI unit of energy is also joule, the same as work.
3. **Forms of Energy:** Energy exists in various forms such as mechanical energy, heat energy, light energy, sound energy, electrical energy, chemical energy and nuclear energy etc. Energy from one form can be transformed into another.
4. **Kinetic energy:** The energy possessed by a body due to its motion is called kinetic energy.
5. **Potential energy:** The energy possessed by a body due to its position is called potential energy.
6. **Law of conservation of energy:** Energy cannot be created nor destroyed, but it can be converted from one form to another.
7. Processes in nature are the result of energy changes. Heat from the Sun causes water of oceans to evaporate to form clouds. As they cool down, they fall down as rain.
8. **Einstein Equation:** Einstein predicted the interconversion of matter and energy by the equation $E = mc^2$.

9. **Nonrenewable resources:** Fossil fuels are known as nonrenewable resources because it took millions of years for them to attain the present form.

10. Sunlight and water power are the renewable resources of energy. They will not run out like coal, oil and gas.

11. Environmental problems such as polluting emission consisting of noise, air pollution and water pollution may arise by using different sources of energy such as fossil fuels, nuclear energy.

12. **Efficiency:** The ratio of the useful work done by a device or machine to the total energy taken up by it is called its efficiency.

13. **Power:** Power is defined as the rate of doing work.

14. **Watt:** The power of a body is one watt which is doing work at the rate of one joule per second.

QUESTIONS

6.1 Encircle the correct answer from the given choices:

i. The work done will be zero when the angle between the force and the distance is

A. 45° B. 60°
C. 90° D. 180°

ii. If the direction of motion of the force is perpendicular to the direction of motion of the body, then work done will be

A. Maximum B. Minimum
C. zero D. None of the above

iii. If the velocity of a body becomes double, then its kinetic energy will

A. remain the same B. become double
C. become four times D. become half

iv. The work done in lifting a brick of mass 2 kg through a height of 5 m above ground will be

A. 2.5 J B. 10 J
C. 50 J D. 100 J

v. The kinetic energy of a body of mass 2 kg is 25 J. its speed is

A. 5 ms^{-1} B. 12.5 ms^{-1}
C. 25 ms^{-1} D. 50 ms^{-1}

vi. Which one of the following converts light energy into electrical energy?

A. electric bulb B. electric generator
C. Photocell D. Electric cell

vii. When a body, is lifted through a height h, the work done on it appears in the form of its:

A. kinetic energy B. potential energy
C. elastic potential energy D. geothermal energy

viii. The energy stored in coal is

A. heat energy
B. kinetic energy
C. chemical energy
D. nuclear energy

ix. The energy stored in a dam is

A. electric energy
B. potential energy
C. kinetic energy
D. thermal energy

x. In Einstein's mass-energy equation, c is the

A. speed of sound
B. speed of light
C. speed of electron
D. speed of Earth

xi. Rate of doing work is called

A. energy
B. torque
C. power
D. momentum.

Answers

i. C	ii. C	iii. C	iv. D	v. A	vi. C
vii. B	viii. C	ix. B	x. B	xi. C	

6.2 Define work. What is its SI unit?

Ans: Work:

Work is done when a force acting on a body displaces it in the direction of a force.

Work is a scalar quantity. It depends on the force acting on a body, displacement of the body and the angle between them.

$$\text{Work done} = \text{Force} \times \text{displacement}$$

or $$W = FS \quad \text{(i)}$$

$$W = F_x \times S$$
$$W = (F\cos\theta)\,S$$
$$W = FS\cos\theta \quad \text{(ii)}$$

Unit of work:

SI unit of work is joule (J). It is defined as

The amount of work is one joule when a force of one newton displaces a body through one metre in the direction of force.

Thus $1\,J = 1\,N \times 1\,m$

6.3 When does a force do work? Explain.

Ans: Work is said to be done when a force acts on a body and moves it in the direction of the force.

Greater is the force acting on a body and longer is the distance moved by it, larger would be the work done. Mathematically, Work is a product of force F and displacement S in the direction of force. Thus

$$\text{Work done} = \text{Force} \times \text{displacement}$$

or $$W = FS \quad \text{............} \quad \text{(i)}$$

If the force is unbalanced, it causes acceleration. This involves doing work to move it in a certain direction.

6.4 Why do we need energy?

Ans: Need of energy:

The energy is an important and fundamental concept in science. It links almost all the natural phenomena. When we say that a body has energy, we mean

that it has the ability to do work. Water running down the stream has the ability to do work, so it possesses energy. The energy of running water can be used to run water mills or water turbines.

Energy exists in various forms such as mechanical energy, heat energy, light energy, sound energy, electrical energy, chemical energy and nuclear energy etc. Energy can be transformed from one form into another.

6.5 Define energy, give two types of mechanical energy.

Ans: Energy:

A body possesses energy if it is capable to do work.

Types of mechanical energy:

Mechanical energy possessed by a body is of two types: kinetic energy and potential energy.

6.6 Define K.E. and derive its relation.

Ans: Kinetic Energy:

The energy possessed by a body due to its motion is called kinetic energy.

Derivation of K.E:

Consider a body of mass m moving with velocity v. The body stops after moving through some distance S due to some opposing force such as force of friction acting on it. The body possesses kinetic energy and is capable to do work against opposing force F until all of its kinetic energy is used up.

$\therefore$ K.E. of the body = Work done by it due to motion

$$K.E. = FS \quad \text{(i)}$$

$$V_i = v$$

$$V_f = 0$$

as $$F = ma$$

$$a = -\frac{F}{m}$$

Since motion is opposed, hence, a is negative. Using 3rd equation of motion:

$$2aS = v_f^2 - v_i^2$$

$$2\left(-\frac{F}{m}\right)S = (0)^2 - (v)^2$$

$$FS = \frac{1}{2}mv^2 \quad \ldots\ldots\ldots \text{(ii)}$$

From Eq. (i) and (ii), we get

$$K.E. = \frac{1}{2}mv^2 \quad \text{(iii)}$$

Equation (iii) gives the $K.E.$ possessed by a body of mass m moving with velocity v.

6.7 Define potential energy and derive its relation.

Ans: Potential Energy:

The energy possessed by a body due to its position is known as its potential energy.

Derivation of P.E:

Let a body of mass m be raised up through height h from the ground. The body will acquire potential energy equal to the work done in lifting it to height h.

Thus Potential energy $P.E. = F \times h$

$$= w \times h$$

(Here weight of the body = w = mg)

$$P.E. = wh = mgh \quad ...... \quad (i)$$

Thus, the potential energy possessed by the body with respect to the ground is mgh and is equal to the work done in lifting it to height h.

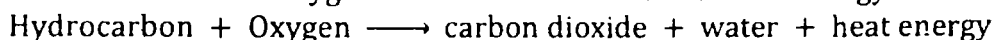
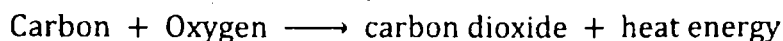
6.8 Why fossils fuels are called non-renewable form of energy?

Ans: Fossil fuels:

Fossil fuels are known as nonrenewable resources because it took millions of years for them to attain the present form.

We use fossil fuels such as coal, oil and gas to heat our houses and run industry and transport. They are usually hydrocarbons (compounds of carbon and hydrogen). When they are burnt, they combine with oxygen from the air. The carbon becomes carbon dioxide; hydrogen becomes hydrogen oxide called water; while energy is released as heat. In case of coal:

$$\text{Carbon} + \text{Oxygen} \longrightarrow \text{carbon dioxide} + \text{heat energy}$$

$$\text{Hydrocarbon} + \text{Oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{heat energy}$$

6.9 Which form of energy is most preferred and why?

Ans: Solar energy is most preferred.

Explanation:

Solar energy is the energy coming from the Sun and is used directly and indirectly. Sunlight does not pollute the environment in any way. The sunrays are the ultimate source of life on the Earth. We are dependent on the Sun for all our food and fuels. If we find a suitable method to use a fraction of the solar energy reaching the Earth, then it would be enough to fulfil our energy requirement.

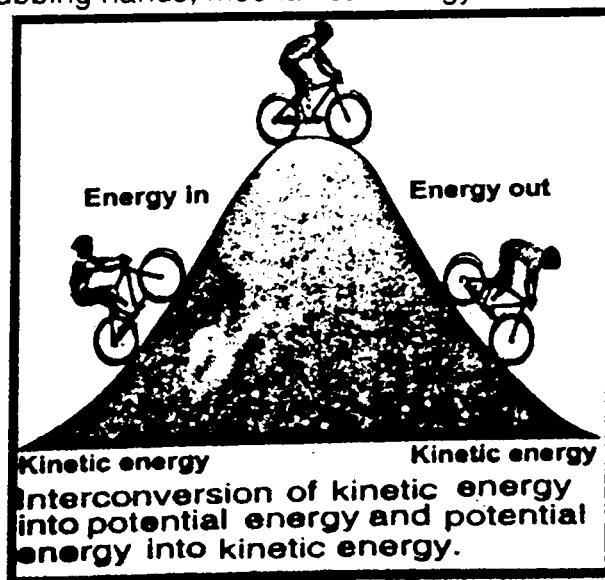
6.10 How is energy converted from one form to another? Explain.

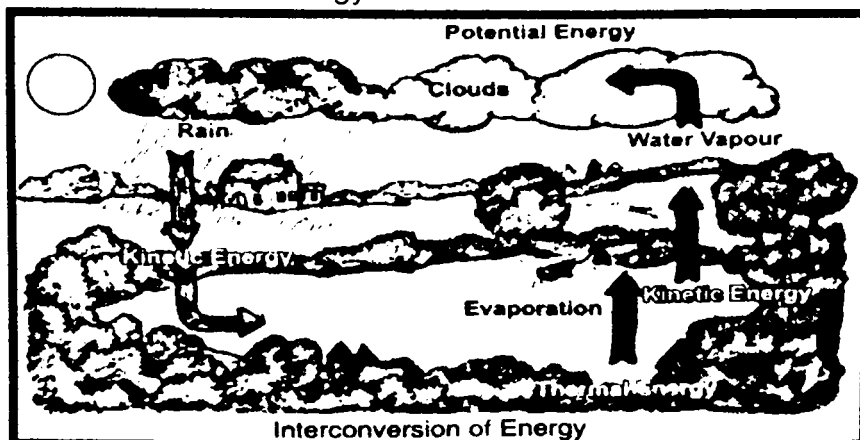
Ans: Interconversion of energy:

Energy cannot be created nor destroyed, but it can be converted from one form to another.

Examples:

i. Rub your hands together quickly. You will feel them warm. You have used your muscular energy in rubbing hands as a result heat is produced. In the process of rubbing hands, mechanical energy is converted into heat energy.

Interconversion of kinetic energy into potential energy and potential energy into kinetic energy.

ii. Processes in nature are the results of energy changes. For example, some of the heat energy from the Sun is taken up by water in the oceans. This increases the thermal energy.

Interconversion of Energy

Thermal energy causes water to evaporate from the surface to form water vapours. These vapours rise up and form clouds. As they cool down, they form water drops and fall down as rain. Potential energy changes to kinetic energy as the rain falls This rain water may reach a lake or a dam. As the rain water flows down, its kinetic energy changes into thermal energy while parts of the kinetic energy of flowing water is used to wash away soil particles of rocks known as soil erosion.

Note:

During the interconversion of energy from one form to other forms, the total energy at any time remains constant.

6.11 Name the five devices that convert electrical energy into mechanical energy.

Ans: **(i)** Electric motor converts electrical energy to mechanical energy.
(ii) Drill machine **(iii)** Electric fan
(iv) Electric spinner **(v)** Electric grinder

6.12 Name a device that converts mechanical energy into electrical energy.

Ans: Electric generator converts mechanical energy into electrical energy.

6.13 What is meant by the efficiency of a system?

Ans: **Efficiency:**

The ratio of the useful work done by a device or machine to the total energy taken up by it is called its efficiency.

OR

Efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input.

$$\text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}} \quad \text{(i)}$$

Or

$$\%\ \text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}} \times 100 \quad \text{(ii)}$$

6.14 How can you find the efficiency of a system?

Ans:

$$\text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}} \quad \text{.......... (i)}$$

Or % Efficiency $= \frac{\text{required form of output}}{\text{total input energy}} \times 100$ (ii)

6.15 What is meant by the term power?

Ans: Power:

Power is defined as the rate of doing work.

Mathematically,

Power $P = \frac{\text{Work done}}{\text{Time taken}}$

or $P = \frac{W}{t}$ .... (i)

Since work is a scalar quantity, therefore, power is also a scalar quantity.

Note: Bigger units of power are kilowatt (kW), megawatt (MW) etc.

$1\text{kW} = 1000\text{W} = 10^3\text{W}$

$1\text{MW} = 1000\,000\text{ W} = 10^6\text{W}$

1 horsepower = 1 hp = 746 W

6.16 Define watt.

Ans: Unit of power:

SI unit of power is watt (W). It is defined as

Watt:

The power of a body is one watt if it does work at the rate of 1 joule per second (1 Js^{-1}).

PROBLEMS

6.1 A man has pulled a cart through 35 m applying a force of 300 N. Find the work done by the man. (10500 J)

Solution: Distance = S = 3.5

Force = F = 300N

Work done = W = ?

$W = F \times S$

$W = 300 \times 35$

$W = 10500\text{ J}$

6.2 A block weighing 20 N is lifted 6 m vertically upward. Calculate the potential energy stored in it. (120 J)

Solution: Weight of the block = w = 20N

Height = h = 6m

Potential energy P.E. = ?

$P.E. = mgh$

We know that $w = mg$

$P.E. = (mg) \times h$

Thus $P.E. = (2 \times 10) \times 6$

$P.E. = 120\text{ J}$

6.3 A car weighing 12 kN has speed of 20 ms^{-1}. Find its kinetic energy. (240 kJ)

Solution: Weight of the car $w = 12\text{kN} = 12 \times 1000\text{N} = 12000\text{N}$

Speed of the car v = $20 ms^{-1}$
Kinetic energy K.E. = ?

$$K.E. = \frac{1}{2} mv^2$$

$$w = mg \quad \text{or} \quad m = \frac{w}{g}$$

$$m = \frac{12000}{10} = \frac{12000}{10} = 1200 \text{ kg}$$

Thus

$$K.E. = \frac{1}{2} \times 1200 \times (20)^2$$
$$= 600 \times 400 = 240000 \text{ J}$$
$$= 240 \times 10^3 \text{ J}$$
$$K.E. = 240 \text{ kJ}$$

6.4 A 500 g stone is thrown up with a velocity of 15 ms^{-1}. Find its
(i) P.E. at its maximum height
(ii) K.E. when it hits the ground (56.25 J, 56.25 J)

Solution: Mass of stone = m = 500 g = $\frac{500}{1000}$ kg = 0.5 kg
Velocity = v = 15 ms^{-1}
(i) Potential energy P.E. = ?
(ii) Kinetic energy K.E.= ?

(i) Loss of K.E. = Gain in P.E.

$$\frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2 = mgh$$

As velocity of the stone at maximum height becomes zero, therefore, $v_f = 0$

$$\frac{1}{2} \times 0.5 \times (0) - \frac{1}{2} \times 0.5 \times (15)^2 = mgh$$
$$-\frac{1}{2} \times 0.5 \times 225 = mgh$$
$$-56.25 = mgh$$
$$mgh = -56.25 \text{J}$$

Since energy is always positive, therefore

$$P.E. = 56.25 \text{ J}$$

(ii)

$$K.E. = \frac{1}{2} mv^2$$
$$K.E. = \frac{1}{2} \times 0.5 \times (15)^2$$
$$= \frac{1}{2} \times 0.5 \times 225$$
$$= 56.25 \text{ J}$$

6.5 On reaching the top of a slope 6 m high from its bottom, a cyclist has a speed of 1.5 ms^{-1}. Find the kinetic energy and the potential energy of the cyclist. The mass of the cyclist and his bicycle is 40kg. (45 J, 2400 J)

Solution: Height of the slope = h = 6 m
Speed of the cyclist = v = 1.5 ms^{-1}
Mass of cyclist and the bicycle = m = 40 kg
(i) Kinetic energy K.E. = ?
(ii) Potential energy P.E. = ?

(i)

$$K.E. = \frac{1}{2} mv^2$$
$$K.E. = \frac{1}{2} \times 40 \times (1.5)^2$$

$= \frac{1}{2} \times 40 \times 2.25 = 45$ J

(ii) P.E. = mgh

P.E. = $40 \times 10 \times 6 = 2400$ J

6.6 A motor boat moves at a steady speed of 4 ms^{-1}. Water resistance acting on it is 4000 N. Calculate the power of its engine. (16 kW)

Solution: Speed of the boat = v = 4 ms^{-1}

Force = F = 4000 N

Power = P = ?

$P = Fv$

$P = 4000 \times 4$

$P = 16000$ W

$P = 16 \times 10^3$ W

$P = 16$ kW

6.7 A man pulls a block with a force of 300 N through 50 m in 60 s. Find the power used by him to pull the block. (250 W)

Solution: Force = F = 300N

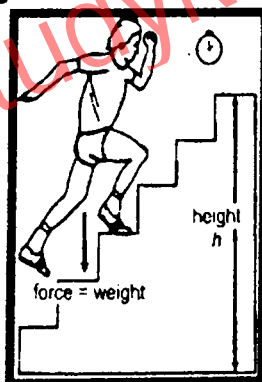
Distance = S = 50m

Time = t = 60s

Power = P = ?

$\text{Power} = \frac{work}{time} = \frac{W}{t} = \frac{F \times S}{t}$

$P = \frac{300 \times 50}{60} = 5 \times 50 = 250$ W

6.8 A 50 kg man moved 25 steps up in 20 seconds. Find his power, if each step is 16 cm high. (100W)

Solution: Mass = m = 50kg

Total height = h = 25×16cm = 400cm = $\frac{400}{100}$ m =4m

Time = t = 20s

Power = P = ?

$\text{Power} = \frac{work}{time} = \frac{W}{t} = \frac{mgh}{t}$

$P = \frac{50 \times 10 \times 4}{20}$

$P = 100$ W

6.9 Calculate the power of a pump which can lift 200 kg of water through a height of 6 m in 10 seconds. (1200 watts)

Solution: Mass = m = 200 kg

Height = h = 6 m
Time = t = 10 s
Power = P = ?

$$\text{Power} = \frac{work}{time} = \frac{W}{t} = \frac{mgh}{t}$$

$$P = \frac{200 \times 10 \times 6}{10}$$

P = 1200 W

6.10 An electric motor of 1hp is used to run water pump. The water pump takes 10 minutes to fill an overhead tank. The tank has a capacity of 800 litres and height of 15 m. Find the actual work done by the electric motor to fill the tank. Also find the efficiency of the system.

(Density of water = 1000 kgm^{-3})
(Mass of 1 litre of water = 1 kg)
(447600 J, 26.8 %)

Solution: Power = P = 1hp = 746 W
Time = t = 10 min. = 10 × 60 s = 600 s
Capacity/volume = V = 800 litres
Height = h = 15 m
(i) Work done = W = ?
(ii) Efficiency = E = ?

$$\text{Power} = \frac{work}{time}$$

$$P = \frac{W}{t}$$

or $W = P \times t$

$W = 746 \times 600$

W = 447600J

Since, the work done by the electric pump to fill the tank is 447600J. It is equal to input.
Hence input = actual work done = W = 447600J
(ii) Output = P.E = mgh
Since 1 litre =1kg, therefore 800 litres = 800kg
Output = P.E = 800× 10× 15 = 120000J

$$\text{Efficiency} = \frac{output}{input} \times 100$$

$$= \frac{120000}{447600} \times 100$$

Efficiency = 26.8 %